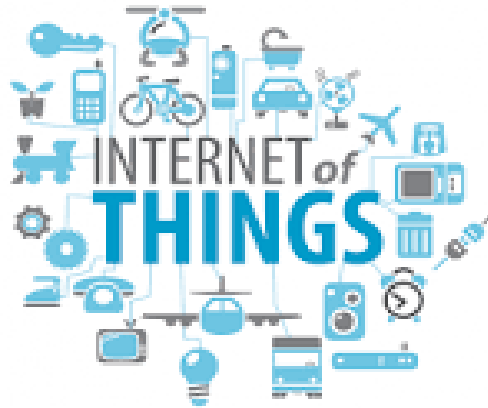


March 2019



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Presentation Overview

- Introduction to the Internet of Things
- IoT in the EMC Environment
- EMC Regulatory Issues for Market Access
- EMC Test Strategies



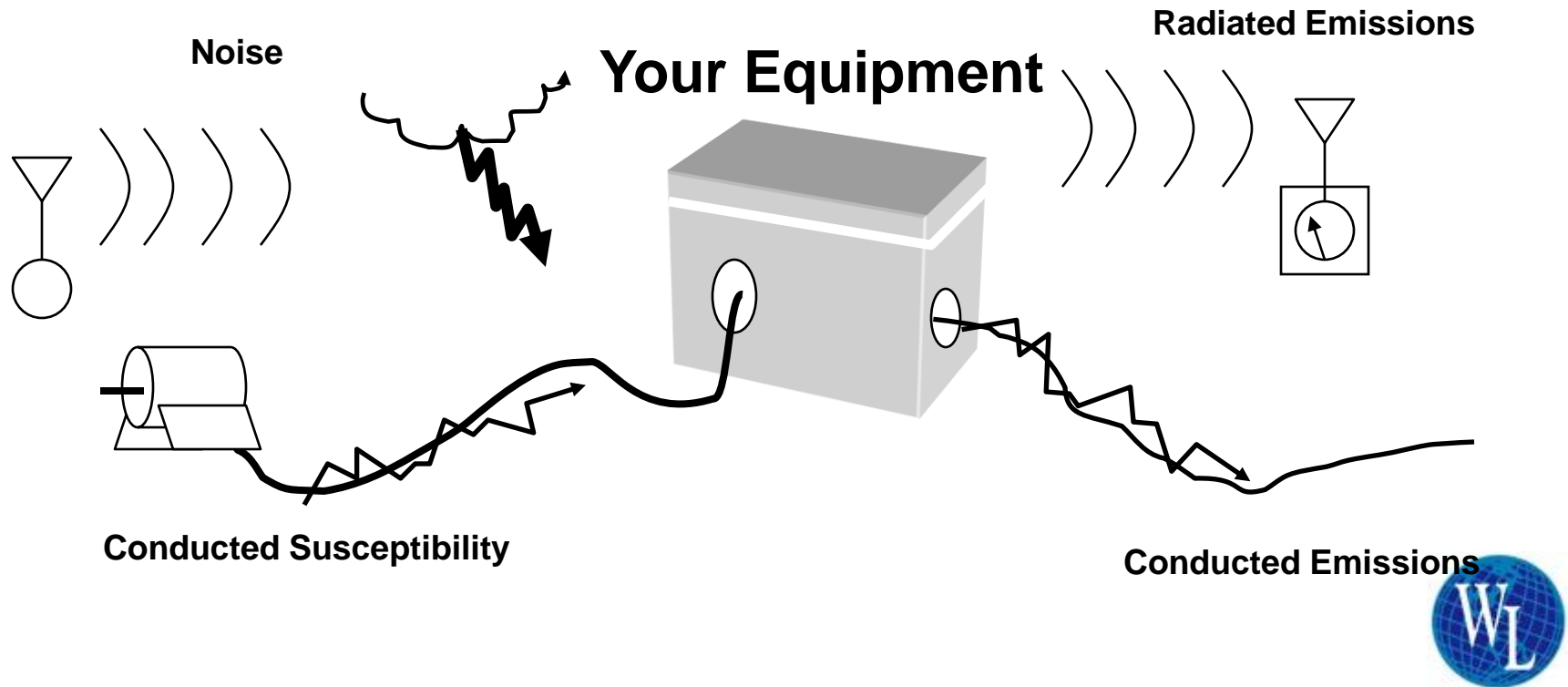
First, some fundamentals

- EMC – Electromagnetic Compatibility
 - The ability to operate in the intended environment without performance degradation
 - The ability to operate in the intended environment without interfering with operation of other equipment/systems



Electromagnetic Compatibility

- **Radiated and conducted interference**
 - Conducted Interference Enters and Exits Equipment through Wiring and Cabling
 - Radiated Interference Enters and Exits Equipment through Wiring and Enclosure Penetration



Introduction to IoT

- Internet of ...
- M2M
- V2X
- 5G
- Cloud/Fog
- EMC throughout



IEEE IoT Initiative



- Composed of 30 Societies and Councils
 - EMC Society, founding member
- “The leader in all things IoT”
- iot.ieee.org



IEEE IoT Initiative

iot.ieee.org

- IoT: “A network of items—each embedded with sensors—which are connected to the Internet.”



<http://iot.ieee.org/>



IoT Initiative

...a place for the global community working on the Internet of Things...

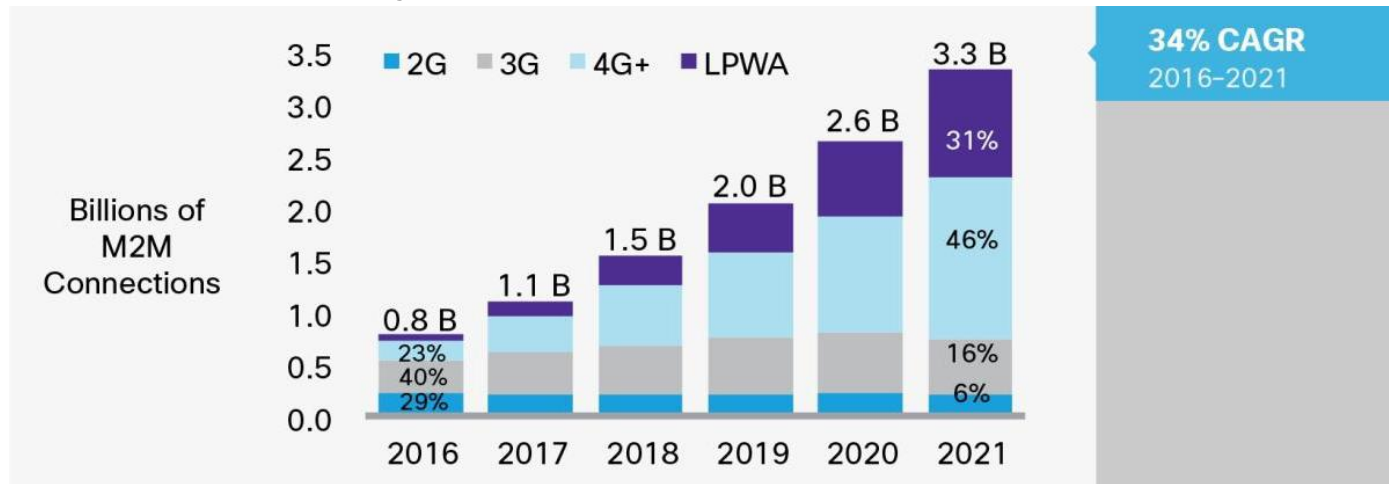
Communications Society
Council on Electronic Design
Automation
Signal Processing Society (SPS)
Standards Association
Computer Society
Standards Association (SA) Staff
Electromagnetic Compatibility Society
Systems, Man and Cybernetics Society
Control Systems Society
Future Directions
Power and Energy Society
Microwave Theory and Techniques
Society
Consumer Electronics Society
Sensors Council (SC)
Reliability Society (RS)
Robotics and Automation Society



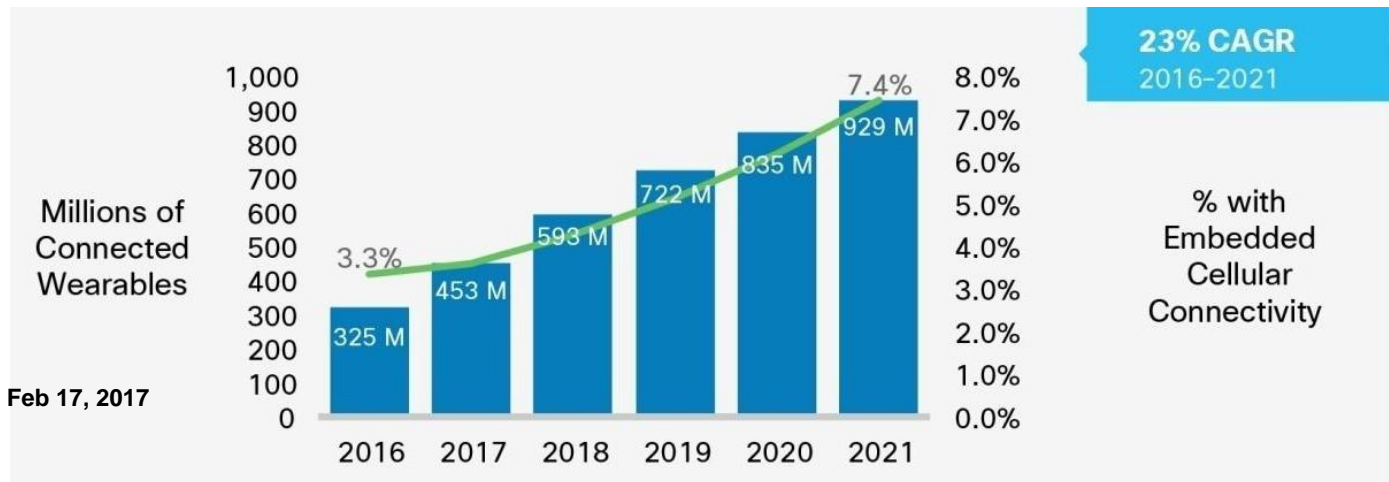
EMC might also take on another meaning: “Every Machine Connected.”

Rise of the Machines

by the numbers...



Source: Cisco VNI Mobile, 2017

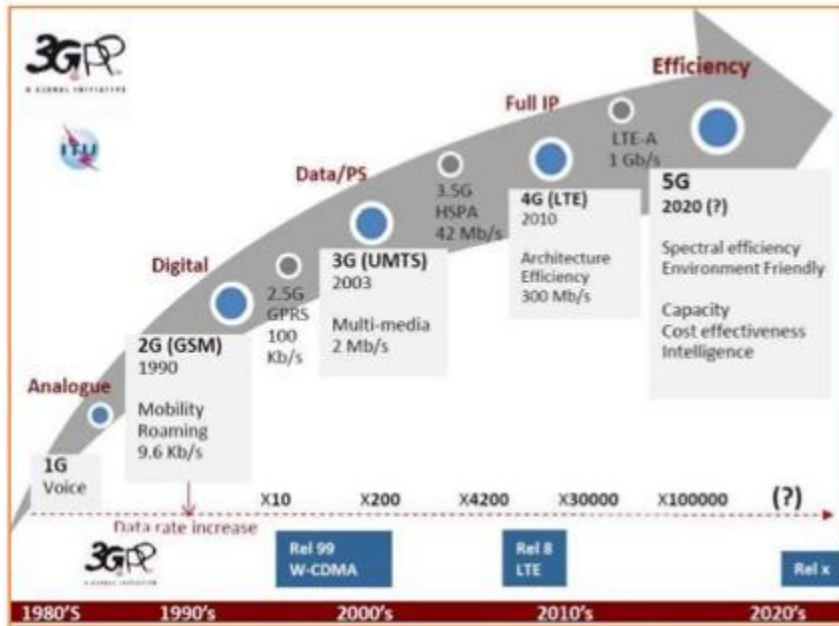


FCC Presentation Feb 17, 2017

Source: Cisco VNI Mobile, 2017



Pace of Advancing Technology

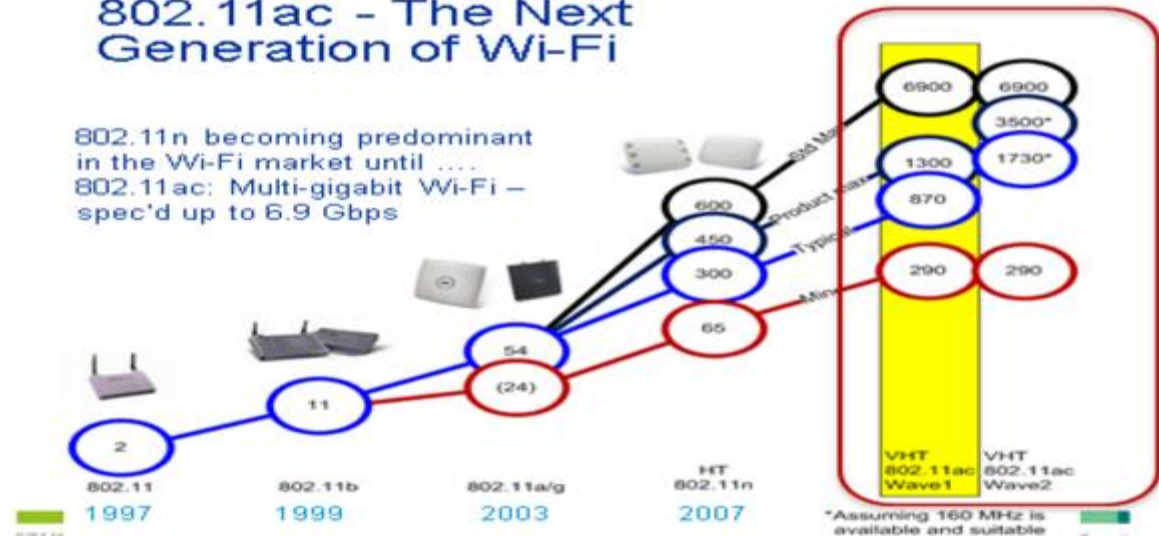


Licensed

802.11ac - The Next Generation of Wi-Fi

802.11n becoming predominant in the Wi-Fi market until
802.11ac: Multi-gigabit Wi-Fi – spec'd up to 6.9 Gbps

Unlicensed

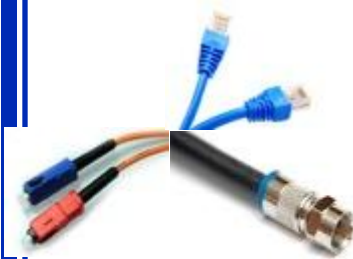


Summary of IoT Technologies

FCC Technological Advisory Council
Graphic Courtesy Bill Morelli, IHS Technologies

Wired

- Ethernet, Coax, Fiber, etc. considered as a single category



WPAN

- ANT+
- Bluetooth – Classic & Smart Ready
- Bluetooth Smart



- ZigBee PRO
- ZigBee RF4CE
- ZigBee Multi-Protocol
- EnOcean
- ISA100.11a
- WirelessHART
- Z-Wave
- Other 802.15.4



WLAN

- 802.11a/b/g
- 802.11n
- 802.11ac
- 802.11ad
- Other 802.11
- DECT ULE
- Other 2.4GHz
- Other Sub-GHz

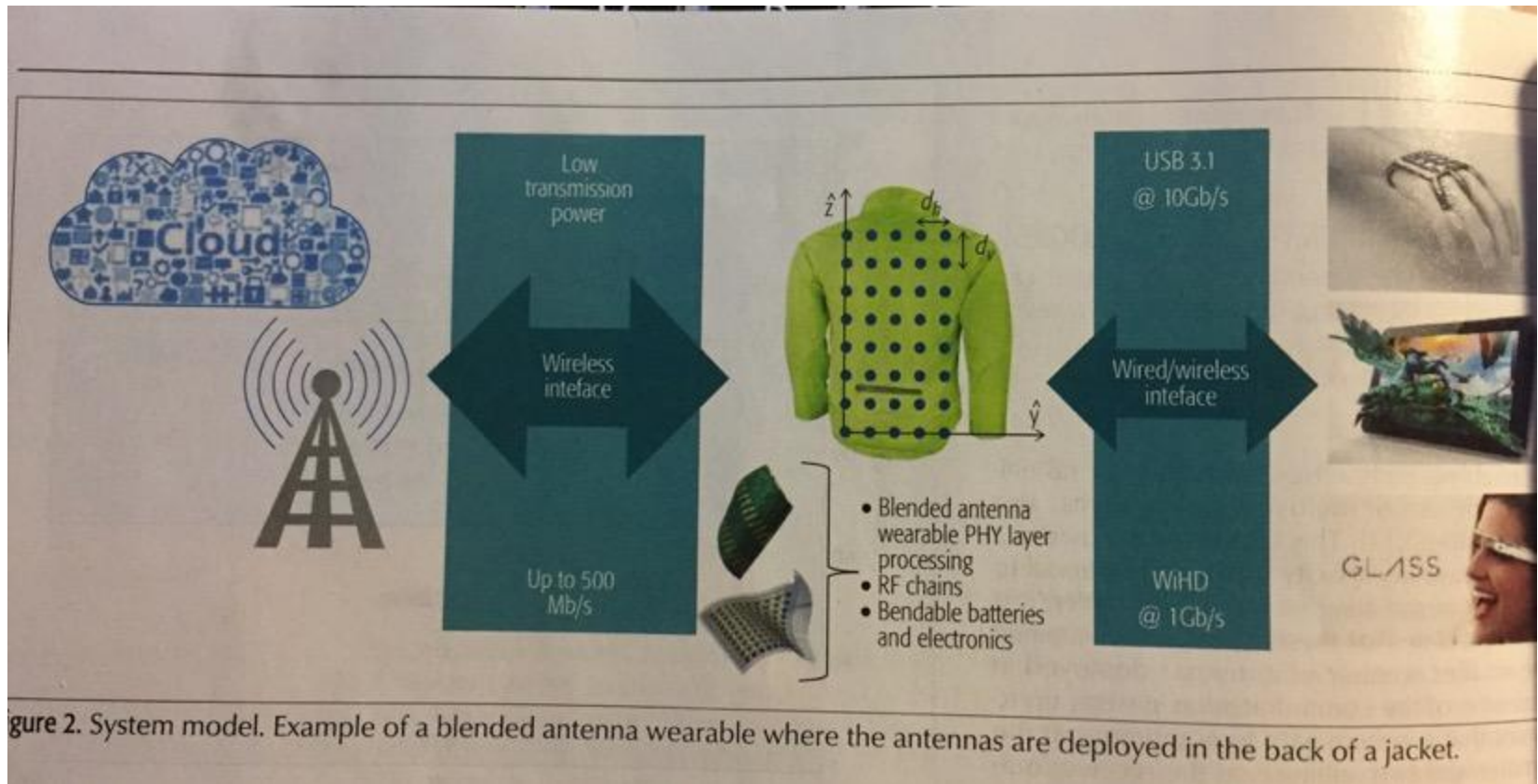


WWAN

- 2G Cellular
- 3G Cellular
- 4G Cellular



Wearables – MIMOmat



“Blended Antenna Wearables for an Unconstrained Mobile Experience.”
IEEE Communications Magazine. April 2017



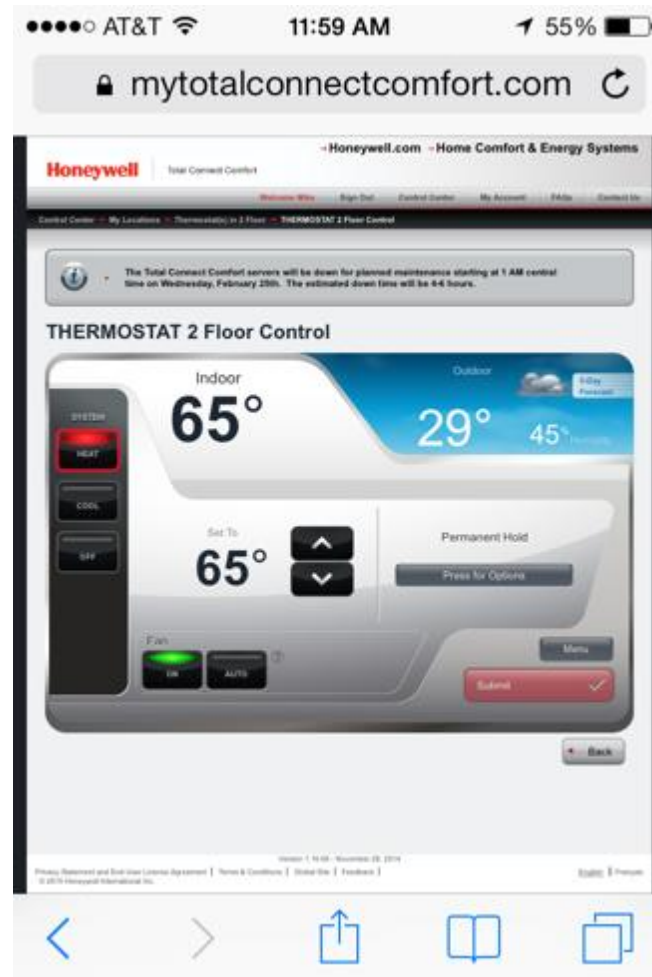
Introduction to IoT

A Personal Journey



Introduction to IoT

Enter WiFi Thermostat



Introduction to IoT

Enter chilly spouse



Actual Bride pictured here:



***For illustrative purposes only**



Oops



WiFi

- 12 Billion devices deployed since 2002, according to the WiFi Alliance
- 3 Billion expected to ship in 2019 and Double Again in 2020
- WiFi Ubiquity



Beijing Coffee Shop



Two Ways to Access the Wireless IoT

- Unlicensed
 - Many modes
 - SRDs
 - LoRA
- Licensed
 - Regular cell networks, LTE, etc.
 - LPWAN
 - 3GPP Release 13/14 (LTE Advanced Pro)



IoT: What is it?

- “A network of items—each embedded with sensors—which are connected to the Internet” (IEEE)
- “IoT is the Integration of the Physical and Digital worlds” (Yanikomeröglu)
- IoT is a “system where the Internet is connected to the physical world via ubiquitous sensors” (OASIS)
- “Anything from a medical instrument to a house key, from a cat to a human being, has the potential to become a node of the Internet.”



•TRENDING

- Verizon forecast: \$585M revenue from M2M

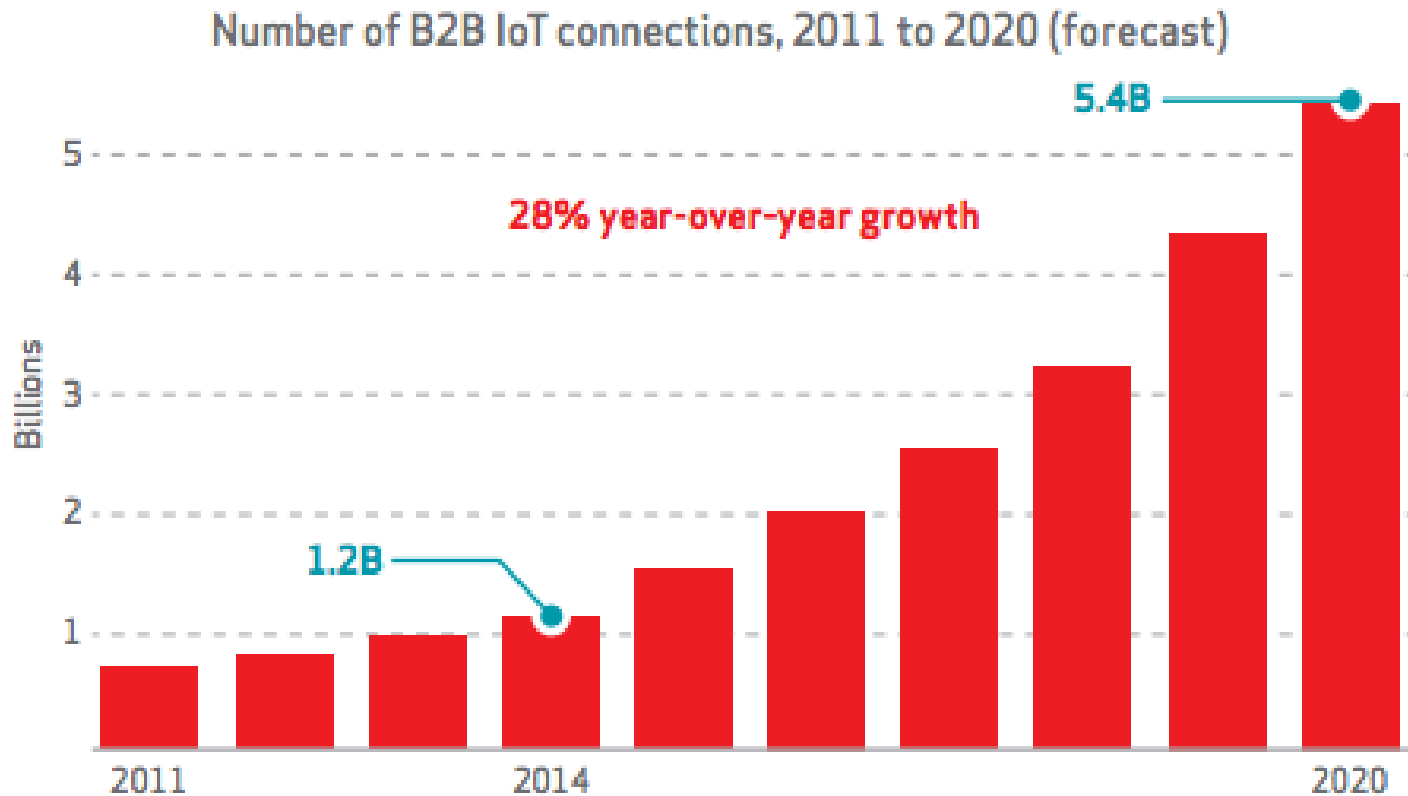


Figure 1: ABI Research for Verizon, 2015¹.



IoT Deployment

Every Conceivable Environment

- Factories
- Residences
- Office
- Agriculture
- Mining
- Retail
- Vehicles

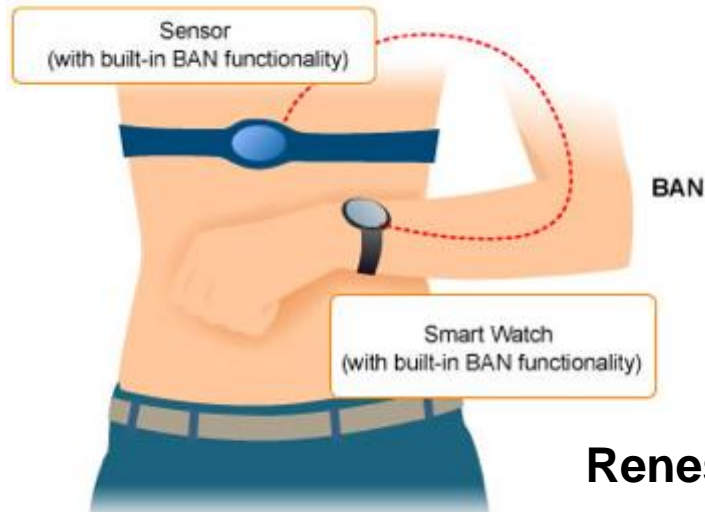


Wearable Technologies



IoT Wearable Technologies

- Smartwatches, etc. use “standard” Bluetooth and Bluetooth Low Energy
- IEEE 802.15.6. Wireless Body Area Networks (WBAN)
- Medical Applications



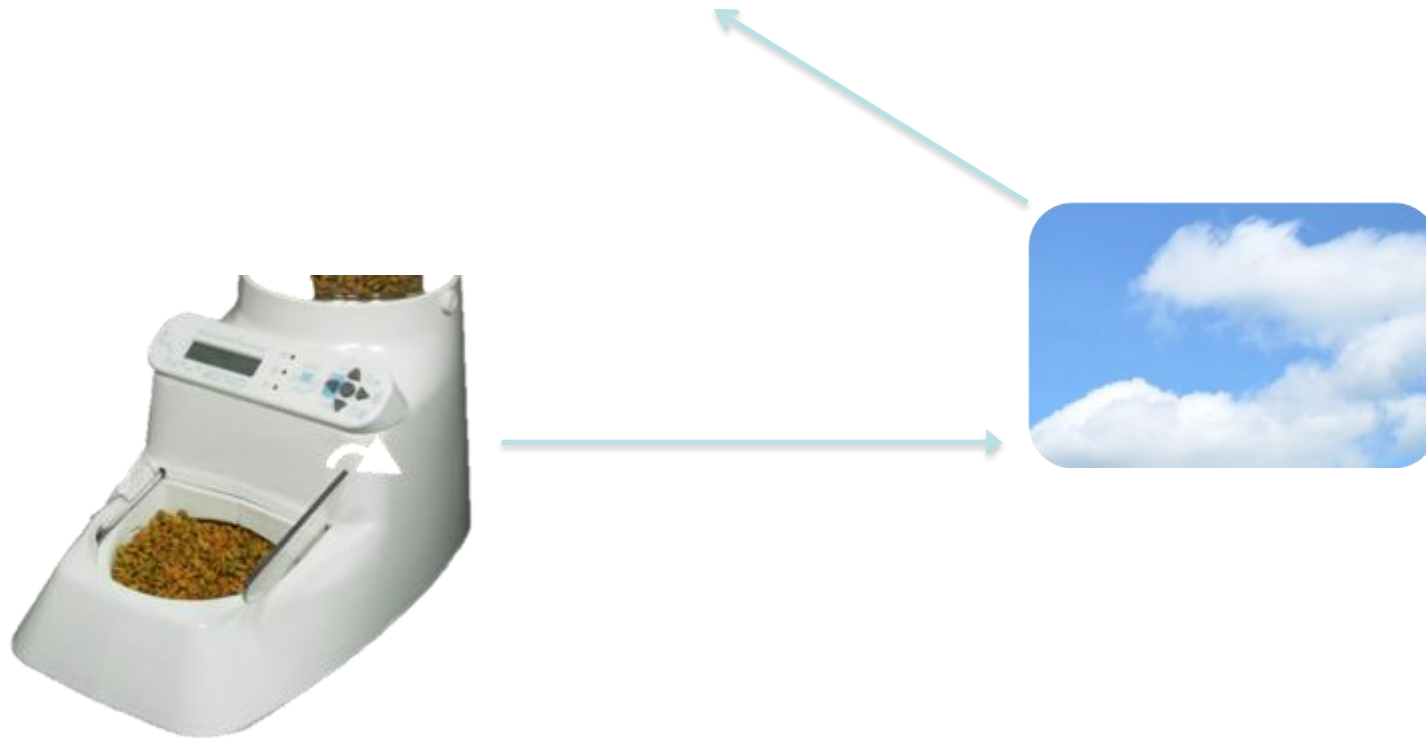
Internet of Cats



Internet of Cats an Illustrative Example



Kitty Re-supply Scenario



Internet of Bicycles

Mobike, OFO, others

- IoT putting bikes on China's streets
- 500,000++!



Industrial IoT (IIoT) Deployment

Duke Energy

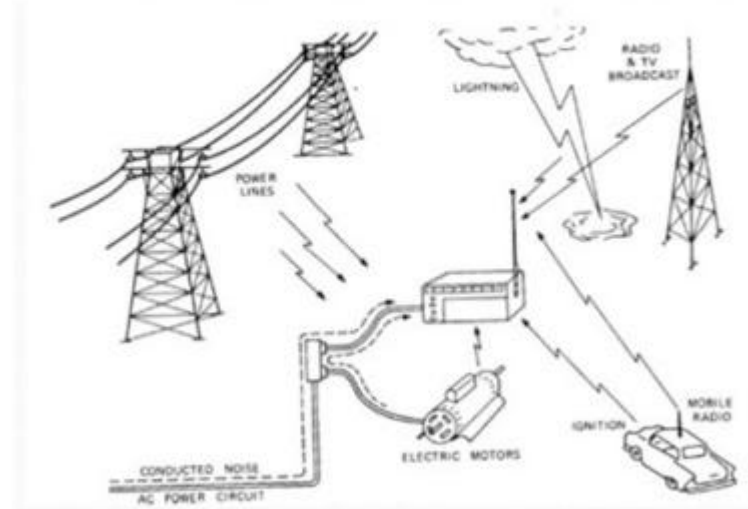
- Identified over 10,000 assets across their facilities, adding more than 30,000 sensors:
- Accelerometers, temperature sensors, oil analysis sensors, thermal cameras and proximity probes
- Vibration, bearing temperature and oil pressure
- Electromagnetic signatures
- Constant data collection; more time for analysis and PM



EMC Environment of IoT

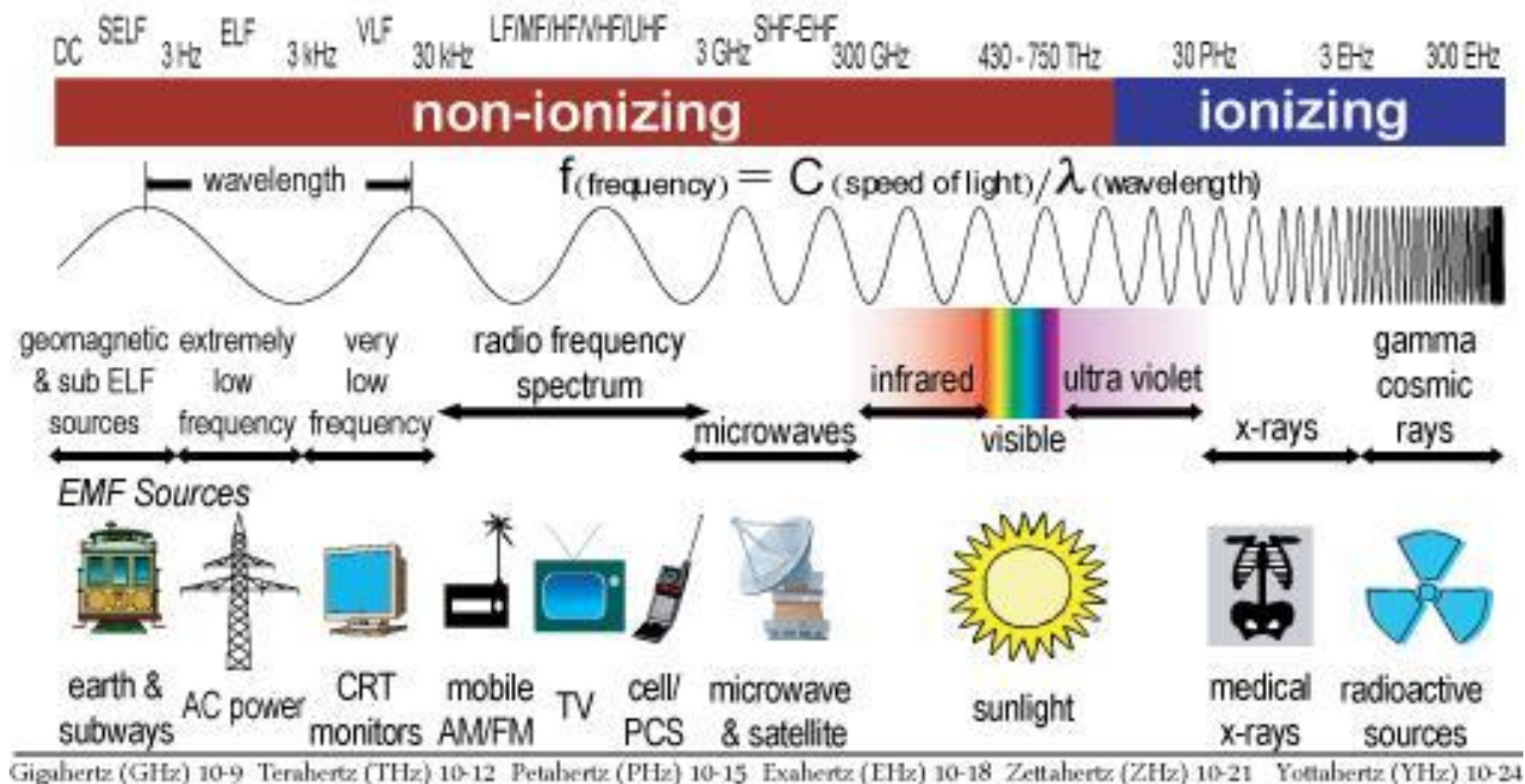
- Natural and Man-Made Noise
- Spectrum contention
- Device density challenges
- Life cycle considerations

Electromagnetic interference (EMI)



EMC Environment of IoT

THE ELECTROMAGNETIC SPECTRUM



Gigahertz (GHz) 10-9 Terahertz (THz) 10-12 Petahertz (PHz) 10-15 Exahertz (EHz) 10-18 Zettahertz (ZHz) 10-21 Yottahertz (YHz) 10-24

Protection of IoT Devices

- Quantify/Define the Electromagnetic Environment
- Design to meet the environment
 - Protection begins with the design and is qualified by proper test & evaluation



Integration of NBIoT

- What service do you need?
 - Data rates?
 - Battery life?
 - Range?
 - Application?
- Design to meet the environment



Integration of NB-IoT

3GPP Narrowband Cellular Standards [\[edit\]](#)

V · T · E [10][11]	LTE Cat 1	LTE-M				NB-IoT		EC-GSM-IoT
		LC-LTE/MTCe	eMTC			LTE Cat NB1	LTE Cat NB2	
		LTE Cat 0	LTE Cat M1	LTE Cat M2	non-BL			
3GPP Release	Release 8	Release 12	Release 13	Release 14	Release 14	Release 13	Release 14	Release 13
Downlink Peak Rate	10 Mbit/s	1 Mbit/s	1 Mbit/s			250 kbit/s		474 kbit/s (EDGE) 2 Mbit/s (EGPRS2B)
Uplink Peak Rate	5 Mbit/s	1 Mbit/s	1 Mbit/s			250 kbit/s (multi-tone) 20 kbit/s (single-tone)		474 kbit/s (EDGE) 2 Mbit/s (EGPRS2B)
Latency	50–100ms	not deployed	10ms–15ms			1.6s–10s		700ms–2s
Number of Antennas	2	1	1			1		1–2
Duplex Mode	Full Duplex	Full or Half Duplex	Full or Half Duplex			Half Duplex		Half Duplex
Device Receive Bandwidth	1.4 – 20 MHz	1.4 – 20 MHz	1.4 MHz			180 kHz		200 kHz
Receiver Chains	2 (MIMO)	1 (SISO)	1 (SISO)			1 (SISO)		1–2
Device Transmit Power	23 dBm	23 dBm	20 / 23 dBm			20 / 23 dBm		23 / 33 dBm

NB IoT

- DL: 250 kbit/s
- UL: 250 kbit/s multitone
- Latency: 1.6s-10s
- Pout: 20/23dBm
- Antennas, SISO
- Half-duplex
- Faster for products to reach market



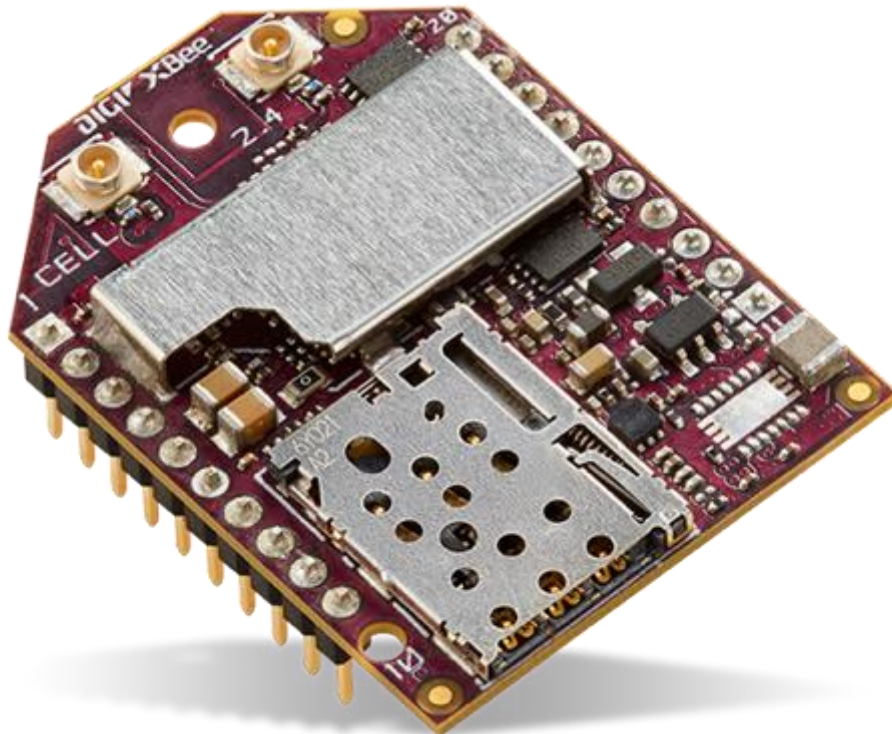
NB IoT Bands

NB-IoT Band	Uplink Band	Downlink Band	Bandwidth	Duplex Mode
B1	1920 - 1980 MHz	2110 - 2170 MHz	60 MHz	HD-FDD
B2	1850 - 1910 MHz	1930 - 1990 MHz	60 MHz	HD-FDD
B3	1710 - 1785 MHz	1805 - 1880 MHz	75 MHz	HD-FDD
B5	824 - 849 MHz	869 - 894 MHz	25 MHz	HD-FDD
B8	880 - 915 MHz	925 - 960 MHz	25 MHz	HD-FDD
B11	1427.9 - 1447.9 MHz	1475.9 - 1495.9 MHz	20 MHz	HD-FDD
B12	699 - 716 MHz	729 - 746 MHz	17 MHz	HD-FDD
B13	777 - 787 MHz	746 - 756 MHz	10 MHz	HD-FDD
B17	704 - 716 MHz	734 - 746 MHz	12 MHz	HD-FDD
B18	815 - 830 MHz	860 - 875 MHz	15 MHz	HD-FDD
B19	830 - 845 MHz	875 - 890 MHz	15 MHz	HD-FDD
B20	832 - 862 MHz	791 - 821 MHz	30 MHz	HD-FDD
B25	1850 - 1915 MHz	1930 - 1995 MHz	65 MHz	HD-FDD
B26	814 - 849 MHz	859 - 894 MHz	35 MHz	HD-FDD
B28	703 - 748 MHz	758 - 803 MHz	45 MHz	HD-FDD
B31	452.5 - 457.5 MHz	462.5 - 467.5 MHz	5 MHz	HD-FDD
B66	1710 - 1780 MHz	2110 - 2200 MHz	70/90 MHz	HD-FDD
B70	1695 - 1710 MHz	1995 - 2020 MHz	25 MHz	HD-FDD



Modular Transmitters

- Make it easier to put modular transmitters in products
- Faster for products to reach market



Modular Transmitters

- Check the regulatory status!
- What markets do you anticipate?

REGULATORY APPROVALS	
FCC (USA)	MCQ-XB3M1
IC (CANADA)	1846A-XB3M1
CE / RED (EUROPE)	Complete



What further testing?

- US: SDoC
 - FCC Part 15 to 10X radio transmitter
- EU: DOC
- Japan: Gitecki mark?



Finally, some related activity



IoT & 5G



- More spectrum/bandwidth!
- Low Latency
- Increasing complexity
- IEEE Future Networks Initiative
- <https://futurenetworks.ieee.org/>



mmWave Coalition

mmwavecoalition.org



- Seeking more use of >95GHz spectrum
- Spectrum Horizons: R&O Feb 22, 2019



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For Immediate Release

FCC TAKES STEPS TO OPEN SPECTRUM HORIZONS FOR NEW SERVICES AND TECHNOLOGIES

WASHINGTON, March 15, 2019—The Federal Communications Commission adopted new rules to encourage the development of new communications technologies and expedite the deployment of new services in the spectrum above 95 GHz. This spectrum has long been considered the outermost horizon of the usable spectrum range, but rapid advancements in radio technology have made these bands especially ripe for new development.



THANK YOU!

Q&A

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